New York State
DEPARTMENT OF ENVIRONMENTAL CONSERVATION

Division of Water

Upper Esopus Creek

Biological Assessment

2009-2010 Survey

New York State
Department of Environmental Conservation

BIOLOGICAL STREAM ASSESSMENT

Upper Esopus Creek
Ulster County, New York - Lower Hudson River Basin

Survey dates: August, 2009 and 2010
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Alexander J. Smith

Stream Biomonitoring Unit
Bureau of Water Assessment and Management
Division of Water
NYS Department of Environmental Conservation
Albany, New York

Survey and Report Participants

Brian T. Duffy, Diana L. Heitzman, Lawrence E. Abele, Jeff L. Lojpersberger, Margaret A. Novak,
NYS Department of Environmental Conservation, Division of Water, Stream Biomonitoring Unit, Bureau of Water Assessment and Management, Albany, New York

Barry P. Baldigo, Mike R. McHale, Scott D. George, Jason Siemion
United States Geological Survey, Department of Interior, Water Science Center, Troy, New York

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River Basin: Lower Hudson River Basin

Reach: Oliverea to Boiceville, NY, NY

Background

The New York State Department of Environmental Conservation (NYSDEC) Stream Biomonitoring Unit (SBU) and United States Geological Survey (USGS) sampled the Upper Esopus Creek and its tributaries, Ulster County, New York, on August 25-27, 2009 and August 17-18, 2010. These surveys were conducted to provide a comprehensive assessment of the biological condition (fish, invertebrates, and algae) and water quality (turbidity and nutrients) that occurs in the Upper Esopus Creek. The results and conclusions presented here cover invertebrate communities only. Reports addressing fish, algae, turbidity and nutrients are in development by the USGS, Troy Water Science Center. Major objectives of this effort were to characterize the natural variability in biological communities, their relationship with water quality, and the potential effects of point sources of turbidity and nutrients. The main goal of this project was to quantify the impact of present water quality concerns on the Upper Esopus Creek, including the influence of turbid water from the Shandaken Tunnel and Stony Clove Creek, and possible nutrient enrichment from Birch Creek and the Village of Phoenicia.

To characterize water quality based on biological community condition, benthic macroinvertebrate communities were sampled from riffle habitats at each site. Methods used are described in the Standard Operating Procedure: Biological Monitoring of Surface Waters in New York State (Smith et al., 2012) and outlined in this document. Funding for this project was provided through the Safe Drinking Water Act.

Results and Conclusions

1. Single site biological assessments for water quality in the Upper Esopus Creek watershed fall within the range of non- to slightly impacted conditions. These conditions reflect good to very good water quality and a macroinvertebrate community indicative of conditions with minimal or limited human impact. Most of the sites assessed as slightly impacted were located downstream of the Shandaken Tunnel and sampled during the summer of 2010.

2. Although water quality above and below the Shandaken Tunnel is assessed as non- or slightly impacted, and thus, supportive of uses, there are significant shifts in biological communities immediately downstream of the Tunnel, compared with upstream sites. These changes were documented using biological impairment criteria, and occurred consistently and in each of the years sampled. Impacts are most frequently due to loss of sensitive taxa.

3. Results suggest the primary driver affecting the magnitude of difference in biological condition downstream of the Shandaken Tunnel is variation in yearly flow condition. Impacts appear to be the result of compounding effects of low flow, warm temperatures, and the deposition of silt. The relative influence from the Shandaken Tunnel during normal flow years provides enough discharge to maintain cooler temperatures and prevent siltation of bottom habitats.

Introduction

The Esopus Creek, located in the south central Catskill Mountain Region of southeastern New York, is part of the New York City (NYC) drinking water supply system. The stream was dammed in 1915 to form the Ashokan Reservoir, splitting the creek into Upper (upstream of the reservoir) and Lower segments. This investigation focuses on the Upper Esopus Creek which follows a 67.3 km semi-circular course from its headwaters at Lake Winnisook, to the Ashokan Reservoir near Boiceville. This portion of the stream drains approximately 497 km^2 of watershed (Figure 1). The entire (upper and lower segments) watershed is within the Catskill Park, draining some of the region's most rugged and mountainous terrain. Forested land comprises over 95% of the watershed and features glacial lacustrine clay deposits that contribute suspended sediment to the system (CCE, 2007).

The Schoharie Reservoir, located 27 miles north of the Ashokan Reservoir, supplies water to the Upper Esopus Creek through a man-made underground channel known as the Shandaken Tunnel (Figure 1). The Shandaken Tunnel joins the Upper Esopus Creek near Allaben, NY approximately 18 km upstream of the Ashokan Reservoir. The Shandaken Tunnel contributes turbid and often cool water to the Upper Esopus Creek. Impacts on biological communities in the Upper Esopus Creek from the condition of Shandaken Tunnel water quality have been a concern for many years (Bode et al., 1995; Bode et al., 2001; Duffy et al., 2011; Smith et al., 2008). However, in 2006 a State Pollution Elimination Discharge (SPDES) permit was issued for the Shandaken Tunnel. This permit set management targets for discharge and turbidity. Since the issuance of this permit there have not been any violations of the turbidity limits and citizen complaints have been drastically reduced (Kenneth Kosinski, NYSDEC, NYC Watershed Section, Personal Communication). In addition to the Shandaken Tunnel nine major tributaries (Table 1) deliver water to the Upper Esopus (Figure 1).

Possible influences on biological community condition exist in the Upper Esopus watershed, although their influence is not well known. These include effluent from the NYCDEP Pine Hill (V) Sewage Treatment Plant which enters the Upper Esopus in Big Indian, NY via Birch Creek (Bode et al., 2005; Bode et al., 2001) and concentrated areas of septic system use in close proximity to the stream, especially in the vicinity of Phoenicia, N.Y. (Duffy et al., 2011; Smith et al., 2008).

Previous studies by the NYSDEC SBU have attempted to characterize impacts from these potential sources of disturbance (Bode et al., 2005; Bode et al., 1995; Bode et al., 2001; Duffy et al., 2011; Smith et al., 2008). However, limited sample frequency and lack of quantified yearly variation in populations prevented definitive conclusions. These investigations by the NYSDEC SBU surveyed benthic macroinvertebrate and algal communities in selected tributaries and the Upper Esopus Creek beginning in the mid 1990s. Sampling typically consisted of single benthic macroinvertebrate or periphyton samples from historical, main-stem Upper Esopus Creek sites, accompanied by limited physicochemical measurements. The result was rapid, qualitative assessments, providing useful information on general biological condition. However, confidence in conclusions was weak because natural variance in community composition was never characterized.

In order to elucidate the effects of potential water quality disturbance in the Upper Esopus Creek watershed, the NYSDEC SBU and the USGS implemented a multi-year survey of biological communities and water chemistries. Specifically, the survey was designed to accurately assess potential impacts from the Shandaken Tunnel, Birch Creek, Stony Clove Creek and the Village of Phoenicia. In addition to the Shandaken Tunnel, the investigation aimed to identify other sources of substantial turbidity and nutrients in the watershed by sampling each of the major tributaries. Replicate sampling of biological communities accompanied by detailed physicochemical measurements helped quantify natural variability. Other concurrent investigations reported separately by the USGS include study of local trout populations, turbidity, and suspended sediment loads. Some of the information collected in these other studies is used here with permission for interpretation of results.

Methods

Study Area

Macroinvertebrate samples were collected from 20 study sites in August of 2009 and 2010 from the Upper Esopus Creek and its major tributaries (Figure 1, Table 1). Of the 20 sites, ten are on tributaries and ten are on the main-stem of the Upper Esopus Creek. Main-stem sites were distributed above and below the Shandaken Tunnel (Figure 1, Table 1) to discriminate between the influence of naturally changing stream characteristics and the tunnel on biological communities. Sampling sites were also positioned above and below the village of Phoenicia (Figure 1, Table 1) and on Stony Clove Creek, a major tributary thought to contribute substantial suspended sediment loads (Figure 1, Table 1).

Sampling stations were divided into drainage size classes of ≤ 40 km^2, 41 - 84 km^2, and $\geq$ 85 km^2. These size classes were developed based on a sampling site ordination using similarity of presence and abundance of macroinvertebrate taxa from each sampling location. Macroinvertebrate abundance data were transformed using Log x+1 to create a Bray Curtis similarity matrix from which non-metric multi-dimensional scaling was applied. Clusters of sites from this ordination were then used to set the boundaries of drainage size classes. These size classes facilitated the evaluation of NYSDEC's biological impairment criteria for flowing waters. Impairment criteria were evaluated against a control site within each of the size classes in the same sampling year (Table 1). For the ≤ 40 km^2 size class the control site was the Esopus Creek at Oliverea (USOP-00), for the 41 - 84 km^2 the control site was Woodland Valley Creek (WODC-01), and for the ≥ 85 km^2 the control site was the Upper Esopus at Allaben (USOP-03A) which is immediately upstream of the Shandaken Tunnel. In the case of the ≥ 85 km^2 class, USOP-03A provided direct comparison with sites downstream of the Shandaken Tunnel, isolating its effects on in-stream conditions.

Biological Assessment

Field, laboratory, and assessment methods followed the *Standard Operating Procedure: Biological Monitoring of Surface Waters in New York State* (NYSDEC, 2012) and *Biological Impairment Criteria for Flowing Waters in New York State* (Bode et al., 1990). Four replicate benthic macroinvertebrate samples were collected from each of the 20 sites in 2009 and 2010. Samples were collected from riffles with cobble and gravel or cobble and boulder substrate by kick-sampling for 2 minutes while proceeding along a diagonal transect downstream for 5 meters (Bode et al., 1990; Smith et al., 2012). A 0.5 m wide, 800 x 900 micron mesh kick net was used. Samples were preserved in 95% ethanol and shipped to a contract laboratory for processing. 100-specimen subsamples were randomly picked from each sample. Specimens were identified to lowest possible taxonomic level.

New York State's multimetric index of biological integrity was used to determine water quality at each of the sites sampled (NYSDEC, 2012). This method calculates species richness, Ephemeroptera–Plecoptera–Trichoptera richness (Lenat, 1988), Hilsenhoff's biotic index score (Hilsenhoff, 1987), and percent model affinity (Novak and Bode, 1992). The result of each of these indices is placed on a common 10 scale and the mean of the adjusted values is calculated. The result, called the Biological Assessment Profile (BAP) score, is a single value for which a four-tiered scale of water quality impact (non-, slight, moderate, or severe) has been established (NYSDEC, 2012).

New York State's biological impairment criteria (Bode et al., 1990) were used to identify sites in the study where aquatic life was significantly degraded compared to control sites. Assessing exceedence of impairment criteria involved the comparison of individual biological assessment metrics and the BAP between upstream control and downstream sampling sites. This method identifies sites which have water quality metric scores that exceed the normal, expected variance between an upstream-downstream or control-test set of locations. Violation of biological impairment criteria do not necessarily mean a water body is not supportive of aquatic life use, rather there is a significant difference in condition between two locations. Individual biological community metrics were averaged from the four replicates and the mean values were used to evaluate provisional impairment levels between sites. The impairment criteria evaluated were: Hilsenhoff's Biotic Index (HBI) +1.5; Ephemeroptera, Plecoptera, Trichoptera, Richness (EPT) -4; Species Richness (Spp) -8; Species Dominance (Dom) +15; Percent Model Affinity (PMA) -20; and Biological Assessment Profile (BAP) -1.25. The threshold for BAP is provisional as it was not part of the original impairment criteria document written by Bode et al. (1990). If provisional impairment was identified, one-way analysis of variance (ANOVA) was performed along with a multiple comparisons test (Holm-Sidak method). This method is a slight deviation from the t-test evaluation of metrics presented in Bode et al. (1990). However, the multiple comparisons test is a more conservative test and allows for identification of threshold exceedence between multiple sites at one time. These tests determined whether statistically significant differences in mean metrics scores existed between control and non-control sites.

All discharge and continuous temperature data collection was conducted by the USGS using standard collection protocols (Wilde et al., 1999). Stream stage was recorded at 15-minute intervals and discharge measurements were made at 8 week intervals and during high flow. Stage-discharge relations were developed for each site to compute the unit discharge. Water temperature was measured at 15-minute intervals using Forest Technology DTS-12 turbidity sensors and Campbell Scientific 547A water conductivity and temperature sensors.

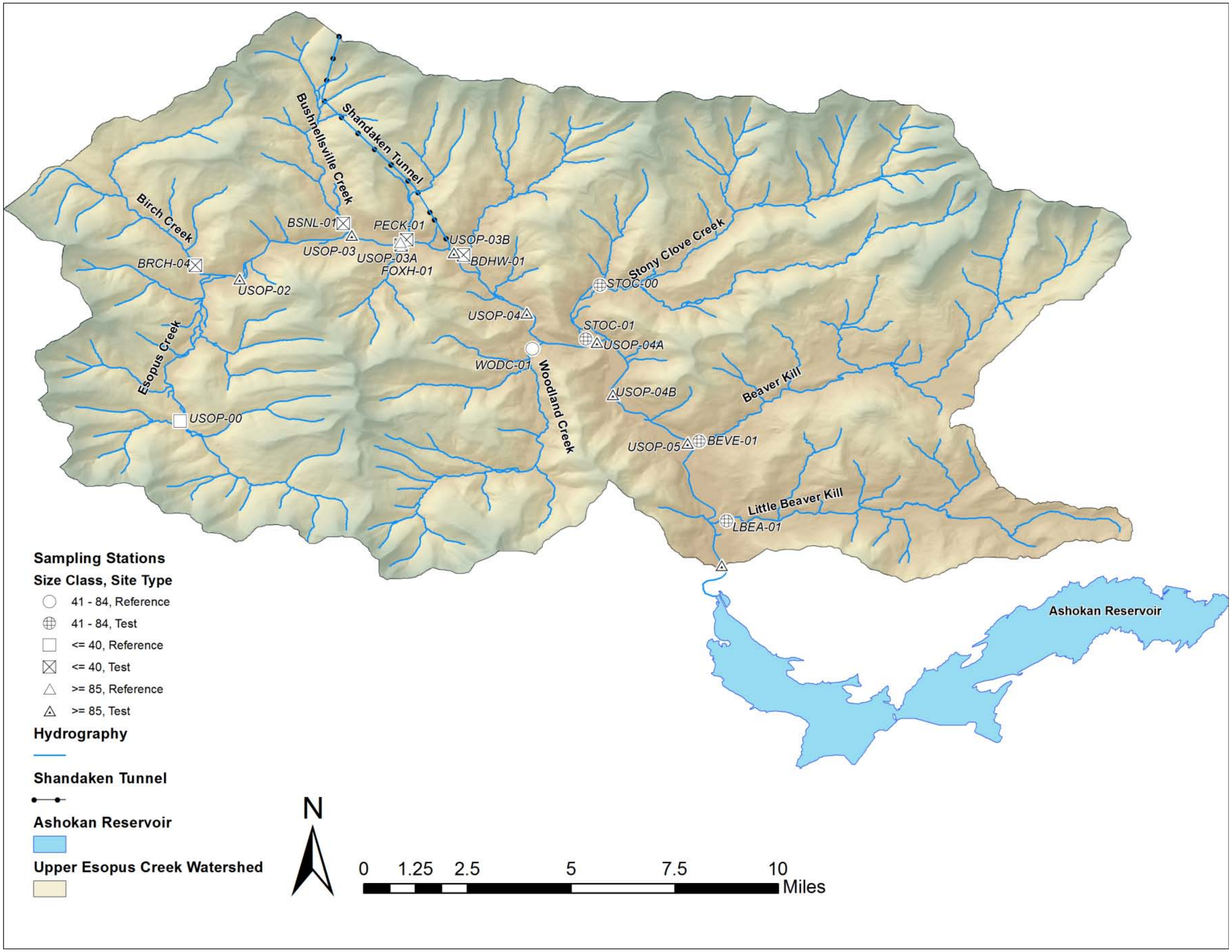

Figure 1. Map of the Upper Esopus Creek watershed showing major tributaries, the Shandaken Tunnel, reservoirs, and sampling locations used in this study.

Results and Discussion

In the Upper Esopus Creek watershed drainage area classification is a good indicator of change in benthic macroinvertebrate community type. Using non-metric multi-dimensional scaling we found sampling sites fell out along a gradient of drainage area based on Bray Curtis species similarity (Figure 2). Ordination results suggest average taxon similarity of 44% between sites within drainage area classes. Average dissimilarity between drainage classes was 66%. Certain groups of macroinvertebrates contributed more than others to similarity between sites within drainage classes. For example, Ephemeroptera steadily increased in percent contribution to site similarity with increased drainage area and had the greatest contribution among sites with drainage area ≥ 85km^2. In contrast, Diptera decreased in percent contribution to site similarity (Figure 3). Future monitoring of biological communities in the Upper Esopus Creek watershed should make comparisons within these drainage classes. This will ensure that biological integrity will be related to the most appropriate baseline condition.

The biological assessment of water quality in the Upper Esopus Creek watershed suggested non-impacted conditions. These conditions reflect very good water quality and a macroinvertebrate community indicative of natural conditions with only minimal human impacts (Smith et al., 2012). However, some sites were assessed as slightly impacted, most of which occurred in the largest drainage class (≥85km2), during the summer of 2010 (Figures 4 and 5, Tables 2, 3, and 4). Assessments of slight impact are considered reflective of a macroinvertebrate community altered from natural conditions but indicative of good water quality (Smith et al., 2012). Previous water quality assessments of the Upper Esopus Creek conducted by the NYSDEC SBU since 1995 suggest fluctuations in condition between non- and slight impact (Bode et al., 2005; Bode et al., 1995; Bode et al., 2001; Duffy et al., 2011).

Most of the samples collected did not result in biological assessment exceeding expected variance thereby violating thresholds for provisional impairment. However, variance exceedence was suggested consistently and regardless of year at main-stem stations USOP-03B and USOP-04, immediately downstream of the Shandaken Tunnel (Figure 1). These exccedences occurred most frequently due to loss of sensitive EPT taxa (Table 4). Additional occurrences happened at stations USOP-04A and USOP-04B but with less consistency (Table 4).

Although the data indicate a distinct impact on biological condition followed by recovery downstream of the Shandaken Tunnel, year to year variation exists in the severity of this impact. The magnitude of difference between upstream and downstream sampling stations is much greater in 2010 than in 2009. The difference is so great that assessment results span multiple impact categories (i.e. non-: BAP score 7.5-10.0 to slight: BAP score 5.0-7.5). This is different from 2009 in which effects from the Shandaken Tunnel were noticeable but assessment results remained well within the non-impacted category (Figure 5).

Table 1. Sampling locations used in the collection of benthic macroinvertebrates in the Upper Esopus Creek Watershed, 2009 and 2010. Drainage area (DA) is provided in square kilometers (km^2), elevation is given in meters (m).

Stream and site name	Site code	Latitude	Longitude	DA (km^2)	Elevation (m)
Fox Hollow	FOXH-01	42.116111	-74.38056	10	309
Peck Hollow	PECK-01	42.125556	-74.37639	12	351
Broadstreet Hollow	BDHW-01	42.112556	-74.35869	24	296
Bushnellsville Creek	BSNL-01	42.124722	-74.40114	30	336
Esopus Creek at Oliverea	USOP-00	42.052500	-74.45622	30	455
Birch Creek	BRCH-04	42.108979	-74.45182	32	377
Little Beaver Kill	LBEA-01	42.019536	-74.26626	43	205
Woodland Valley Creek	WODC-01	42.079722	-74.33458	53	268
Beaver Kill	BEVE-01	42.046758	-74.27681	65	214
Stony Clove Creek	STOC-00	42.102028	-74.31089	80	292
Stony Clove Creek	STOC-01	42.083056	-74.31583	84	245
Esopus Creek at Big Indian	USOP-02	42.104167	-74.43583	112	355
Esopus Creek at Shandaken	USOP-03	42.119444	-74.39750	152	317
Esopus Creek at Allaben	USOP-03A	42.117034	-74.38015	165	305
Esopus Creek downstream of Portal	USOP-03B	42.113333	-74.36189	181	287
Esopus Creek upstream of Phoenicia	USOP-04	42.092500	-74.33597	216	268
Esopus Creek at Phoenicia	USOP-04A	42.081944	-74.31203	357	238
Esopus Creek downstream of Phoenicia	USOP-04B	42.063611	-74.30639	365	225
Esopus Creek at Mt Tremper	USOP-05	42.046889	-74.28000	373	207
Esopus Creek at Boiceville	USOP-06	42.014259	-74.27043	497	189

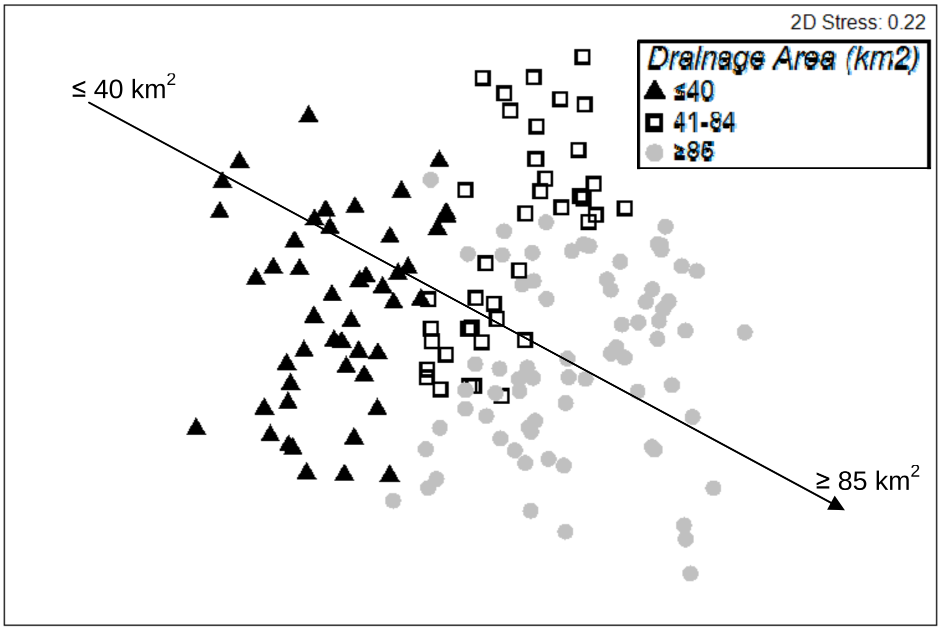

Figure 2. Non-metric multi-dimensional scaling plot of sampling locations in the Upper Esopus Creek watershed. The ordination is based on Bray Curtis similarity using Log x+1 transformed benthic macroinvertebrate species information.

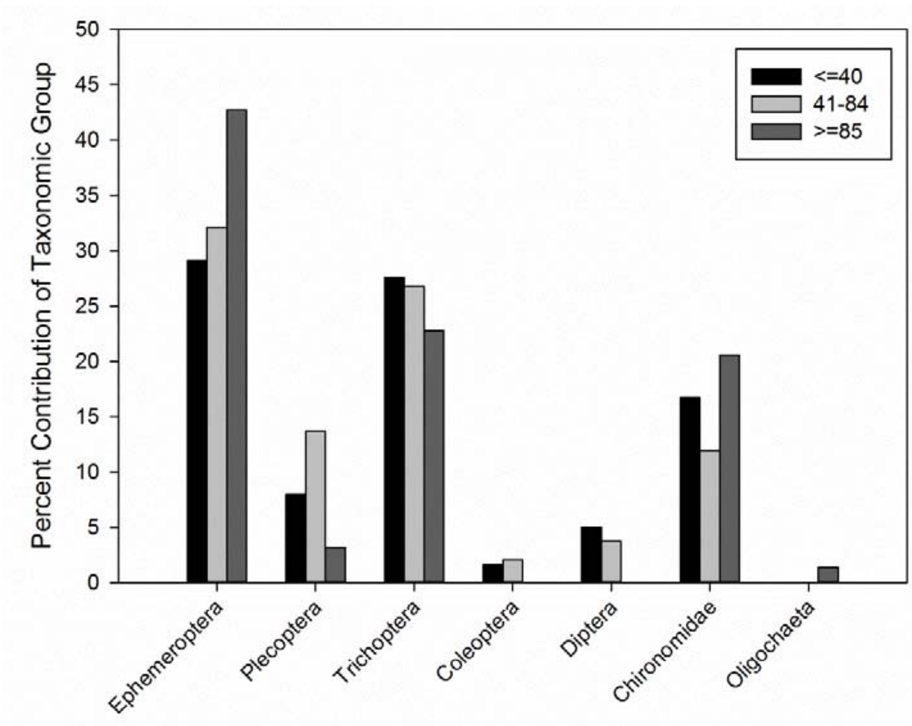

Figure 3. Percent contribution of dominant macroinvertebrate groups to sampling site similarity among drainage area size classes. Certain groups such as Ephemeroptera showed increasing contribution to site similarity as drainage area increased. Others such as the Trichoptera or Diptera suggest the opposite.

Year to year variability in stream discharge, temperature, and siltation explain some of the variability in impact from the Shandaken Tunnel on biological integrity. Both stream discharge and temperature show abrupt differences between sampling stations immediately upstream and downstream of the Shandaken Tunnel (Figure 6). These physicochemical changes are reflected in similar changes in the biological assessment data at these same sites (Figure 5). Therefore, we can infer the variability in biological impact is coupled with the annual percent contribution of flow from the Shandaken Tunnel to the Upper Esopus Creek. Subsequently, temperature and siltation reflect the yearly variability in discharge with colder, less variable temperature, and minimal siltation of substrates in normal flow years (2009). The opposite is true in lower flow years (2010).

Continuous discharge data show mean summer discharge in 2009 was approximately 150 cfs at USOP-03A, upstream of the confluence with the Shandaken Tunnel. After the confluence, discharge more than doubled to 400 cfs at USOP-03B. Moving downstream, discharge continues to increase as additional tributaries enter the stream (Figure 6). During the low flow year of 2010 we see the influence of the Shandaken Tunnel is even more significant, with flow increasing from 31cfs upstream at USOP-03A to 350 cfs downstream at USOP-03B, approximately eleven times the upstream discharge (Figure 6). Unlike 2009, discharge remains nearly constant in 2010 downstream of the Shandaken Tunnel. Less water was contributed by tributaries during the summer months of that year. Variability in discharge such as this has been shown to negatively influence macroinvertebrate communities in other systems. For example, regulated peak discharge downstream of a large reservoir significantly reduced invertebrate densities and caused compositional shifts in the community (Robinson et al., 2003).

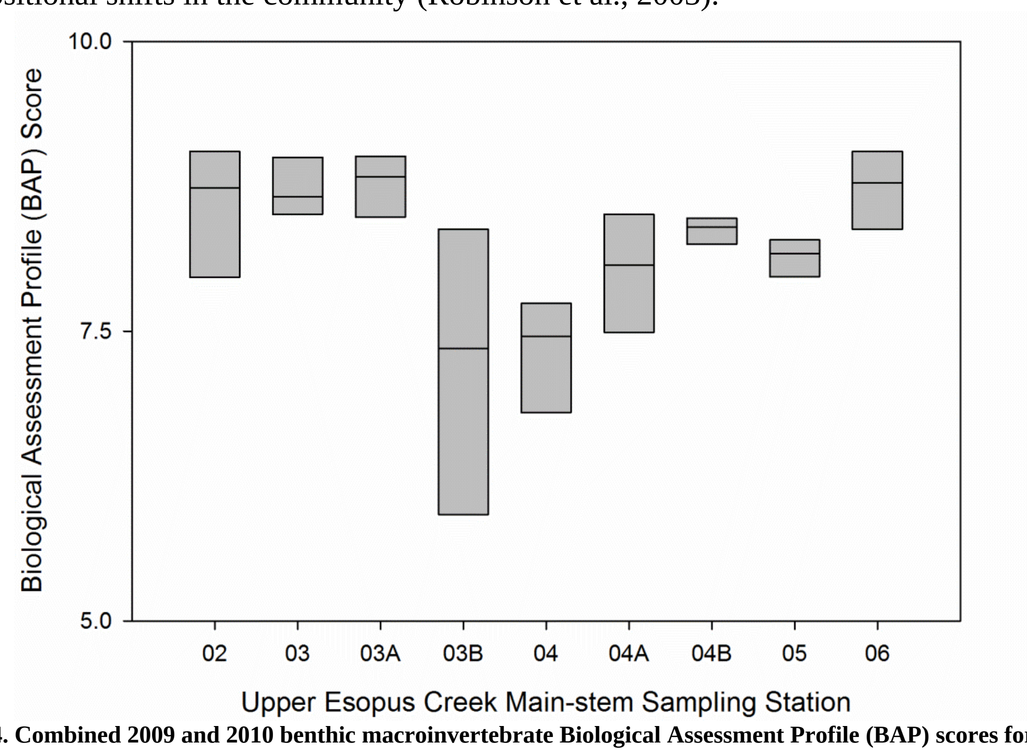

Figure 4. Combined 2009 and 2010 benthic macroinvertebrate Biological Assessment Profile (BAP) scores for main-stem Upper Esopus Creek sampling stations. Mean BAP scores are represented as lines in each box. The confluence of the Shandaken Tunnel is located between stations 03A and 03B. Note the statistically significant decline in biological condition beginning with station 03B.

The difference in flow between years affected temperature regimes and the amount of silt settling on bottom substrates. During 2009 when annual discharge was higher, in-situ temperature measurements at each sampling location were cooler than 2010 temperatures. Both years the same trend is noticeable where temperatures increase continually downstream of the Shandaken Tunnel. However, in 2009 there was a notable decrease in temperature from immediately upstream to immediately downstream of the confluence with the Shandaken Tunnel. Conversely, in 2010 temperatures remained the same or increase slightly from upstream (Figure 6).

Continuous temperature data from station immediately upstream (USOP-03A) and downstream of the portal (USOP-03B) shows the difference in temperature regimes across the two years of study (Figure 7). Temperature was consistently warmer upstream of the Shandaken Tunnel and differences were less between the two sampling locations during the normal flow year of 2009. In 2010 temperatures peaked much higher than in 2009, were more variable, and differences between stations were greater (figure 7). Therefore, temperatures in the Upper Esopus Creek downstream of the confluence of the Shandaken Tunnel generally reflect water temperatures from the Schoharie Reservoir. In normal flow years such as 2009 the Shandaken Tunnel has a cooling affect on water temperatures in the Upper Esopus (figure 7) from its deep water reservoir release. Rarely during the growing season when temperatures reach their highest, do temperatures in the Shandaken Tunnel match those from upstream of the confluence. However, in August 2010 when water levels were down throughout the watershed, temperatures in the Shandaken Tunnel and downstream of the tunnel (USOP-03B) were similar to temperatures upstream (USOP-03A).

The degree of siltation to bottom substrates in the Upper Esopus Creek corresponds with discharge and likely plays a role in limiting benthic macroinvertebrate community development. Higher flows in 2009 may have prevented silt from the Shandaken Tunnel and tributaries like Stoney Clove creek from settling onto bottom substrates. During low flows (2010) data suggest siltation increases continually moving downstream, including downstream of the Shandaken Tunnel (Figure 6). The suspension of sediment such as that noted in higher flow years can cause disturbance to the macroinvertebrate community, greatly increasing macroinvertebrate drift in the water column (Brooker and Hemsworth, 1978) and reducing overall invertebrate density (Gray and Ward, 1982). However, settling of this suspended material, which is observed during lower flow years, can be even more detrimental to biological condition. For instance, sedimentation has been linked to negative effects on benthic macroinvertebrates through reduction in food availability and habitat, reducing rates of growth and reproduction (Henley et al., 2000).

The results of our investigation suggest the difference in biological condition between reaches upstream and downstream of the Shandaken Tunnel is influenced by yearly flow conditions. When mean summer discharge is approximately 200cfs or higher upstream of the Shandaken Tunnel, biological integrity will be maintained. When upstream mean summer discharge is lower than 200cfs and the Shandaken Tunnel is more than 3 times the upstream discharge, the biological condition may become more impacted. The primary drivers of this impairment appear to be compounding effects of low flow, warm temperatures, and the deposition of silt. The relative influence from the Shandaken Tunnel during normal flow years provides enough discharge to maintain cooler temperatures and prevent siltation of bottom habitat.

These findings should provide unique assistance to water and wildlife resource managers working in the Upper Esopus Creek watershed. From this study we now have reliable information on the extent and severity of effects from the Shandaken Tunnel. Additionally, we have an understanding that, of the possible sources of impact to biological communities (Birch Creek, Village of Phoenicia, or Shandaken Tunnel), the tunnel appears to have the most significant effect. Furthermore, the relationship between discharge, temperature, siltation, and biological condition provides a management endpoint with several variables to control. Using the results of this study, improved management of Shandaken Tunnel releases can minimize stress on biological communities.

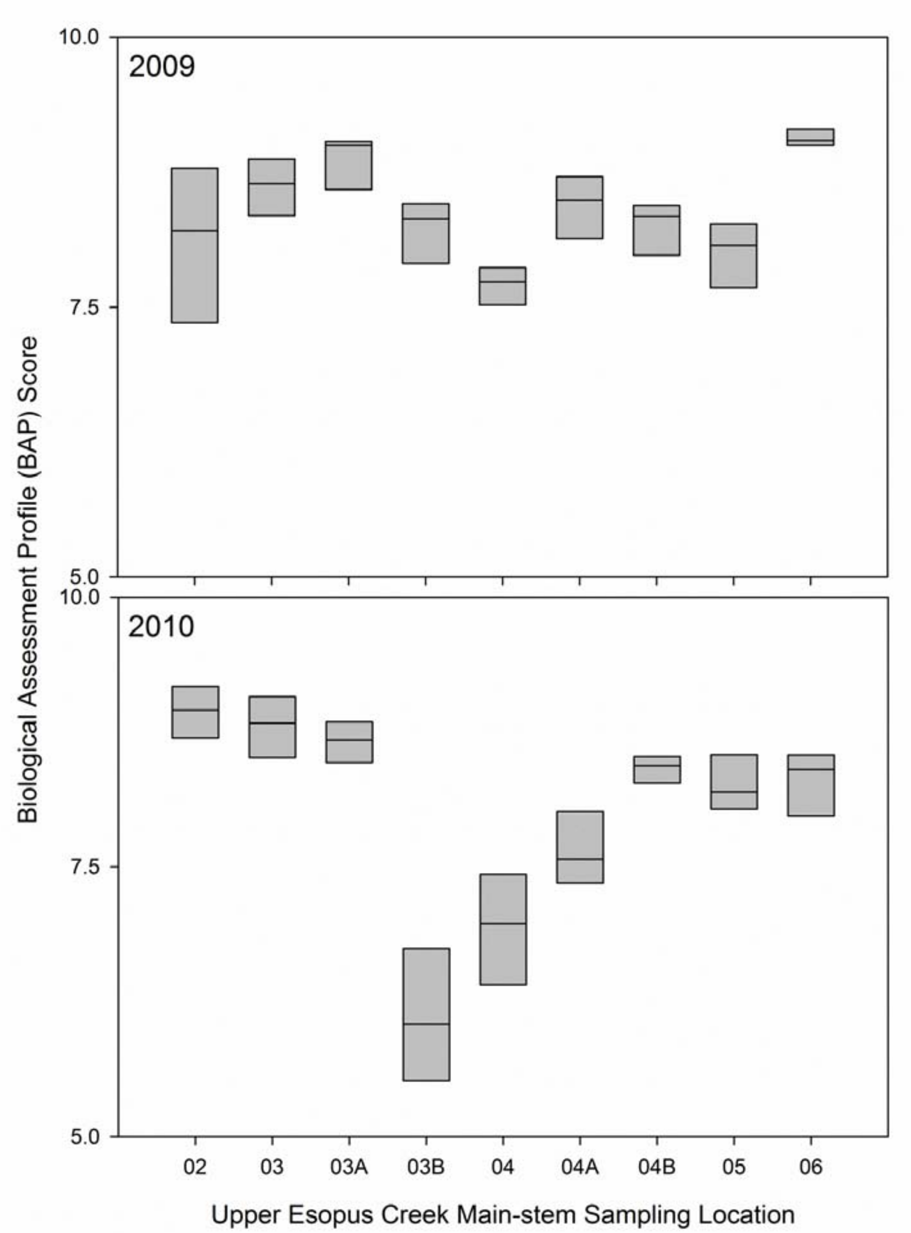

Figure 5. Biological Assessment Profile (BAP) scores for all main-stem Upper Esopus Creek sampling stations in 2009 and 2010. The difference in influence from the Shandaken Tunnel on assessment results between the two years is distinct (station 03A – above the Tunnel, and station 03B – below the Tunnel).

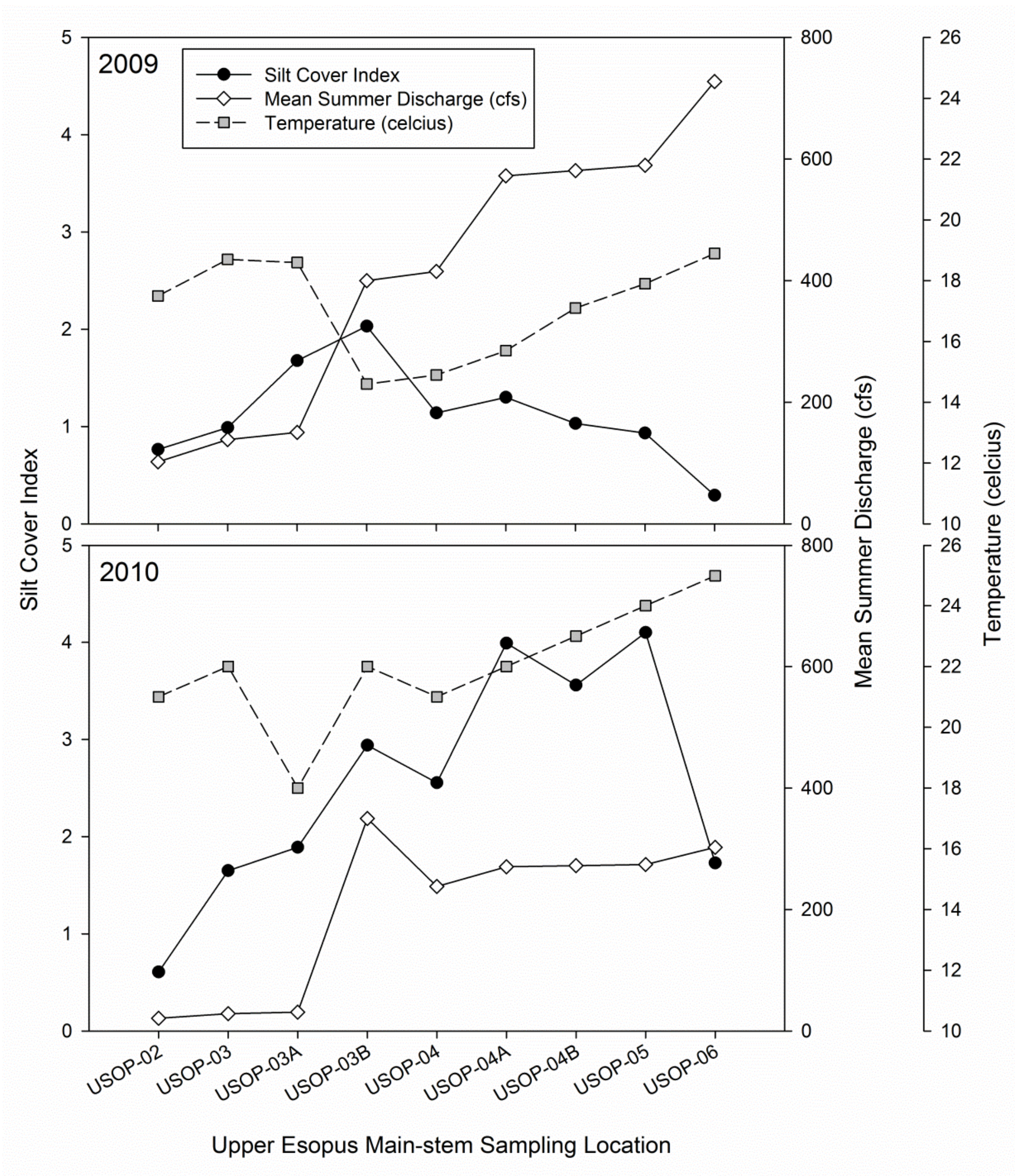

Figure 6. Mean summer discharge, instantaneous temperature, and silt cover index results from main-stem Upper Esopus Creek sampling stations during 2009 and 2010.

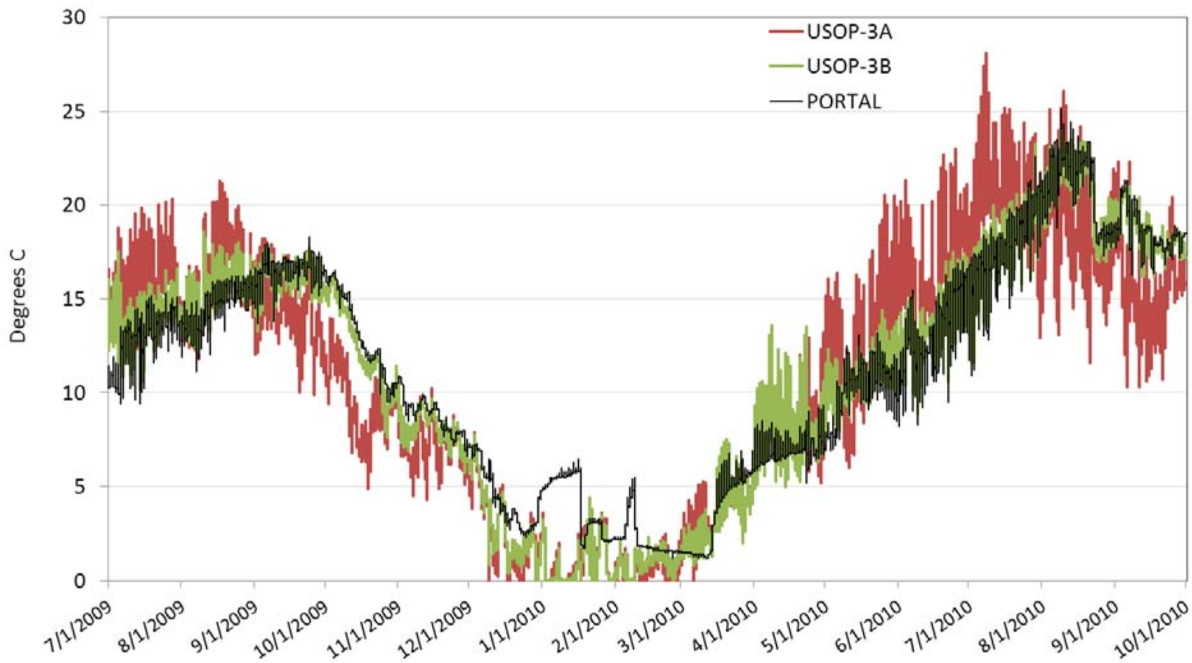

Figure 7. Continuous temperature measured upstream of the Shandaken Tunnel (USOP-03A), downstream (USOP-03B), and from the Shandaken Tunnel (Portal) from July 2009 through September 2010. Note the greater variability of temperatures upstream of the Shandaken Tunnel. During August, 2010, temperatures at all three locations were relatively equal, the result of low flows and warm water releases from the Schoharie Reservoir through the Shandaken Tunnel.

Table 2. Summary statistics of component metrics included in the Biological Assessment Profile score (BAP) as well as the multimetric BAP score for study sites within the ≤ 40 km² size class arranged by location and year. Means represent the average of the four replicate samples collected at each location. Standard deviation (Std) and coefficient of variation (CV) is also provided for each metric. * Identifies the control site for this group. Pattern filled cells indicate statistical exceedence of impairment criteria.

Location	Year	Spp			HBI			EPT			PMA			BAP		
		Mean	Std	CV	Mean	Std	CV	Mean	Std	CV	Mean	Std	CV	Mean	Std	CV
*USOP-00	2009	25.50	1.73	6.79	2.8	0.46	16.42	16	2.06	13.09	73	4.43	6.12	8.6	0.34	3.92
	2010	31.50	3.11	9.87	3.7	0.32	8.56	15	0.58	3.98	57	7.53	13.21	8.3	0.50	6.03
FOXH-01	2009	24.00	4.97	20.69	3.2	0.08	2.61	18	3.70	21.12	75	6.55	8.76	8.5	0.52	6.09
	2010	29.50	5.00	16.95	3.4	0.20	5.94	20	4.12	21.14	68	17.06	25.18	8.6	0.95	11.05
PECK-01	2009	22.25	1.89	8.51	3.3	0.22	6.61	16	1.50	9.23	52	5.29	10.18	7.6	0.36	4.73
	2010	32.25	1.50	4.65	3.4	0.34	10.14	20	1.73	8.88	74	9.47	12.88	9.1	0.24	2.70
BDHW-01	2009	21.75	1.50	6.90	3.4	0.16	4.79	14	1.50	10.53	68	5.19	7.66	8.0	0.34	4.29
	2010	32.25	0.96	2.97	3.4	0.37	10.93	19	0.58	3.12	71	5.80	8.19	9.0	0.27	3.05
BSNL-01	2009	18.75	3.20	17.07	3.0	0.30	9.96	13	3.30	24.94	70	7.87	11.25	7.7	0.75	9.69
	2010	25.25	1.71	6.76	2.8	0.35	12.41	16	1.63	10.21	70	6.19	8.91	8.6	0.21	2.51
BRCH-04	2009	28.75	2.06	7.17	3.6	0.27	7.32	18	0.96	5.39	77	6.68	8.68	8.8	0.26	2.89
	2010	31.00	4.69	15.13	2.8	0.39	13.80	19	2.38	12.87	79	7.79	9.86	9.2	0.39	4.28

Table 3. Summary statistics of component metrics included in the Biological Assessment Profile score (BAP) as well as the multimetric BAP score for study sites within the 41 - 84 km² size class arranged by location and year. Means represent the average of the four replicate samples collected at each location. Standard deviation (Std) and coefficient of variation (CV) is also provided for each metric. * Identifies the control site for this group.

Location	Year	Spp			HBI			EPT			PMA			BAP		
		Mean	Std	CV	Mean	Std	CV	Mean	Std	CV	Mean	Std	CV	Mean	Std	CV
*WODC-01	2009	22.00	1.83	8.30	3.2	0.14	4.53	17	2.38	14.43	75	4.11	5.50	8.3	0.34	4.11
	2010	27.75	3.30	11.91	4.2	0.19	4.47	15	1.29	8.90	67	4.36	6.55	8.2	0.38	4.63
LBEA-01	2009	20.00	2.94	14.72	2.8	0.47	17.03	15	1.71	11.58	66	11.92	18.06	8.0	0.73	9.17
	2010	27.25	2.63	9.65	3.0	0.05	1.62	18	3.46	19.25	63	13.87	22.19	8.4	0.57	6.73
BEVE-01	2009	25.50	1.29	5.06	3.6	0.22	5.98	18	0.50	2.74	77	2.38	3.11	8.6	0.14	1.58
	2010	23.25	2.50	10.75	2.8	0.45	15.97	15	1.29	8.90	59	9.54	16.31	8.0	0.50	6.27
STOC-00	2009	25.00	0.82	3.27	3.9	0.10	2.62	15	0.50	3.28	69	4.43	6.47	8.3	0.12	1.47
	2010	27.25	1.71	6.27	3.1	0.27	8.77	17	1.50	8.70	74	3.40	4.61	8.8	0.04	0.44
STOC-01	2009	26.50	3.11	11.73	4.0	0.25	6.37	18	3.00	17.14	64	4.57	7.12	8.2	0.28	3.40
	2010	25.50	3.87	15.19	4.2	0.21	4.94	15	1.00	6.90	67	5.38	8.06	8.1	0.40	4.91

Table 4. Summary statistics of component metrics included in the Biological Assessment Profile score (BAP) as well as the multimetric BAP score for study sites within the ≥ 85 km^{2} ^{2} size class arranged by location and year. Means represent the average of the four replicate samples collected at each location. Standard deviation (Std) and coefficient of variation (CV) is also provided for each metric. * Identifies the control site for this group. Pattern filled cells indicate statistical exceedence of impairment criteria.

Location	Year	Spp			HBI			EPT			PMA			BAP		
		Mean	Std	CV	Mean	Std	CV	Mean	Std	CV	Mean	Std	CV	Mean	Std	CV
USOP-02	2009	23.75	3.30	13.91	4.1	0.43	10.53	14	2.63	19.13	77	8.88	11.50	8.1	0.76	9.38
	2010	27.25	2.63	9.65	3.0	0.22	7.23	17	2.50	14.93	81	4.11	5.09	8.9	0.26	2.87
USOP-03	2009	25.00	1.83	7.30	3.3	0.31	9.42	18	1.73	9.90	77	3.32	4.34	8.6	0.28	3.24
	2010	26.25	2.63	10.02	2.7	0.41	15.13	17	2.45	14.41	75	2.63	3.49	8.8	0.30	3.40
*USOP-03A	2009	29.25	4.19	14.34	3.6	0.16	4.35	21	2.65	12.91	77	3.30	4.30	8.9	0.28	3.13
	2010	25.00	1.15	4.62	2.9	0.27	9.29	18	2.22	12.49	74	6.38	8.62	8.7	0.20	2.29
USOP-03B	2009	24.75	2.22	8.96	3.6	0.11	2.90	15	1.26	8.53	67	2.06	3.09	8.2	0.30	3.71
	2010	21.50	2.89	13.43	5.5	0.32	5.74	8	1.71	22.04	55	8.54	15.46	6.1	0.63	10.40
USOP-04	2009	21.00	1.41	6.73	4.2	0.24	5.56	13	0.82	6.28	72	5.80	8.12	7.7	0.19	2.48
	2010	17.75	4.79	26.97	4.9	0.17	3.47	11	3.30	29.37	69	8.77	12.76	6.9	0.54	7.83
USOP-04A	2009	26.75	3.30	12.35	4.3	0.12	2.91	18	2.16	12.00	74	3.70	5.03	8.4	0.31	3.65
	2010	21.75	3.86	17.76	4.6	0.15	3.25	15	2.75	18.06	66	5.19	7.83	7.6	0.35	4.64
USOP-04B	2009	24.25	1.71	7.04	4.2	0.34	8.07	16	0.82	5.10	73	4.86	6.63	8.3	0.26	3.16
	2010	25.50	1.29	5.06	4.1	0.17	4.18	16	0.50	3.17	74	7.35	9.93	8.4	0.13	1.54
USOP-05	2009	21.75	1.26	5.79	3.3	0.23	7.15	18	1.73	9.90	64	7.59	11.96	8.0	0.31	3.92
	2010	23.50	1.00	4.26	4.0	0.27	6.84	15	1.73	11.95	78	2.50	3.19	8.3	0.27	3.31
USOP-06	2009	30.25	0.96	3.17	3.6	0.29	8.26	19	2.16	11.37	81	5.23	6.45	9.1	0.08	0.90
	2010	23.25	1.26	5.41	3.5	0.20	5.50	16	2.22	14.08	74	7.50	10.10	8.3	0.32	3.81

Table 5. Macroinvertebrate taxa collected from the Upper Esopus Creek watershed during the 2009 sampling season.

Taxon	BDHW-01	BEVE-01	BRCH-04	BSNL-01	FOXH-01	LBEA-01	PECK-01	STOC-00	STOC-01	WODC-01	USOP-00	USOP-02	USOP-03	USOP-03A	USOP-03B	USOP-04	USOP-04A	USOP-04B	USOP-05	USOP-06
Acentrella turbida	15	69	17	25	20	20		30	33	32	14	38	36	48	101	51	43	40	28	14
Acroneuria abnormis	6	3	1		15	16	6			4	2		1	1	1		1		1	4
Acroneuria carolinensis			4				2							1						
Acroneuria sp.						1		1								1		1	2	2
Agapetus sp.																				1
Agnetina capitata	13	9	8	2	1		23	14	27	1	4	1	9	9	3			2		2
Antocha sp.		1	4		2			1		1		1		1	1	1	2	1	1	5
Apatania sp.			4	49	6		3				1	2	3	2	3					
Atherix sp.										1	4									
Baetis flavistriga	13	2	14	7	18	3	3	12	9	9	25	20	4	9	1	9	7	5	15	
Baetis intercalaris		21				20		1	5					2		1		4	16	40
Baetis tricaudatus	12	26	48	16	21		1	34	6	6	33	48	19	26	37	21	25	9	1	9
Blephoricera sp.					1															
Brachycentrus americanus			4	19							45	4		1						
Brachycentrus appalachia									1		40	2	1							
Caenis sp.																	1	1		
Cambarus sp.			1			1														1
Cardiocladius obscurus		1		1		1		2	1			1	1	1	2		1	3		
Chaetocladius sp.																				1
Cheumatopsyche sp.	14	10	1	2	27	14	25	5	16	6	13	2	3	5	1	1	6	7	5	11
Chimarra aterrima?						5														
Undet. Chloroperlidae				1					1		3									
Corydalus cornutus																				2
Cricotopus bicinctus														1	8					
Cricotopus sp.				1					3			5			3		2			
Demicryptochironomus sp.																	1			

Taxon	BDHW-01	BEVE-01	BRCH-04	BSNL-01	FOXH-01	LBEA-01	PECK-01	STOC-00	STOC-01	WODC-01	USOP-00	USOP-02	USOP-03	USOP-03A	USOP-03B	USOP-04	USOP-04A	USOP-04B	USOP-05	USOP-06
Diamesa sp.				2	1	2	1		1				1							
Dicranota sp.			11				6				1	1								
Diphetor hageni					2		1						1				1			
Diplectrona sp.					2	1														
Dolophilodes sp.	10	15	13	16	19	10	26		2	19	8	2	35	15	2	18	7	8	2	19
Drunella cornutella			12	40	22		2	1		1	42	5				4	3		1	
Undet. Empididae											1							1		1
Undet. Enchytraeidae	1																			
Epeorus sp.	3	17	1			39		2	2	1		1	1	6	1			1	4	8
Ephemera sp.	2																			
Ephemerella sp.	17	2	11	1	5			10	11	13	7	20	26	38	92	28	25	12	15	1
Eukiefferiella brevicalcar gr.				1							2									
Eukiefferiella claripennis gr.											1									
Eukiefferiella devonica gr.	2		2			1			1		1			1	3					
Eukiefferiella pseudomontana gr.	1				1			3	1	1	3	1								
Eukiefferiella sp.			1					1			2									
Eurylophella funeralis							1													
Glossosoma sp.	7	4			1	6	2	3						1						2
Undet. Gomphidae													1							1
Heptagenia sp.			17	34	37		13	1	1	23	13	2	9	6	8	3	9	3	14	2
Hexatoma sp.	11	9	12	16	14	1	12	8	8	8	7	2		3						
Hydropsyche bronta		4	1					13	25	10		2	14	11	13	10	23	12	10	2
Hydropsyche morosa		12	21	1				15	31	2		14	2	23	22	24	45	33	41	20
Hydropsyche slossonae	21	18	11	2	19	3	27	16	12	9	11	4	2	7	9	2	8			1
Hydropsyche sp.								2					1							
Hydropsyche sparna	17	22	17	4	10	17	23	11	12	10	1	8	9	11	5	21	6	10	2	4
Isogenoides sp.	6	10		1		1	1	4	7	14		5	9	4	1	1	2	2		1

Taxon	BDHW-01	BEVE-01	BRCH-04	BSNL-01	FOXH-01	LBEA-01	PECK-01	STOC-00	STOC-01	WODC-01	USOP-00	USOP-02	USOP-03	USOP-03A	USOP-03B	USOP-04	USOP-04A	USOP-04B	USOP-05	USOP-06
Isonychia sp.	8	8	6		8			19	13	44		4	33	24	15	2	10	20	58	47
Lepidostoma sp.	1	1		1	5			1	2	1	5	2		2	1		3	2	29	7
Leucrocuta sp.	1			1		6	9		1	1	1		7		1		4	1	9	5
Leuctra sp.			5	4	13		8					1	1		1					
Limonia sp.	1																			
Macronychus glabratus						1														
Malirekus iroquois			1		1		2									1				
Micropsectra dives gr.	140	30	46	126	83		160	103	62	117	58	56	80	42	5	39	22	29	11	1
Micropsectra polita															2					
Microtendipes pedellus gr.		1				2		1								1	1		1	
Microtendipes rydalensis gr.		5				1			2			1				3	3	3	2	4
Microtendipes sp.								1												
Neophylax sp.			2	1			1													
Neoplasta sp.																				1
Nigronia serricornis	9	1				4														
Ophiogomphus sp.											1									
Optioservus ovalis	13		8		1		9		2		1		1	2				2		
Optioservus sp.			4	2	1						1	1		2	2					5
Optioservus trivittatus												3							1	
Orthocladius (Symposiocladius) lignicola					1															
Orthocladius dubitatus														1	1				2	
Orthocladius sp.			1					10	1	2	7	4	4		3	3	2	1		1
Oulimnius latiusculus			1				2				1									
Pagastia orthogonia	1		1		1			1		1		1			3					1
Parachaetocladius sp.			1					1							1	1		1		
Paragnetina immarginata	18	16	1			27	5	25	13	9			3	7	1	1	2	6	4	17
Paragnetina media						4														6

Taxon	BDHW-01	BEVE-01	BRCH-04	BSNL-01	FOXH-01	LBEA-01	PECK-01	STOC-00	STOC-01	WODC-01	USOP-00	USOP-02	USOP-03	USOP-03A	USOP-03B	USOP-04	USOP-04A	USOP-04B	USOP-05	USOP-06
Paragnetina sp.							1													
Parakiefferiella sp.									1											
Paraleptophlebia sp.		1	4	9	3		1	3	3	5	2	1	2	1			4			
Parametriocnemus sp.			1	1	1		2			1			1			1				
Undet. Perlodidae					3									2						
Physella sp.																	1			
Pisidium sp.			1																	
Plauditus sp.		6			1	7		1			9	1	2	6	5	19	15	7	9	6
Polycentropus sp.							1													
Polypedilum (Tripodura) sp.																	8			
Polypedilum aviceps	5	35	2	4	16	34	1	6	14	2	3	10	2	9		22	25	29	2	15
Polypedilum flavum		12						16	35			7	17	18	9	55	34	53	20	38
Polypedilum tritum			1				1													
Potthastia gaedii gr.									2					1	1					
Potthastia longimana gr.															3					
Procladius sp.															1					
Promoresia tardella			2								3									
Prostoma graecense															1	2				1
Psephenus herricki	22	5				13		1	6	1				2						5
Psilotreta sp.			2						2			14	3	2					2	
Pteronarcys biloba	4				7	3		1	1					1				1		
Pteronarcys proteus	1																			
Pteronarcys sp.		1	3	2			3				2			1						
Rheocricotopus robacki		1				1			1						1			1		
Rheocricotopus sp.			1								1									
Rheotanytarsus sp.			2				1			1	2	19	1	2						
Rhyacophila carolina?						3														
Rhyacophila fuscula		2	14			2	1	1			1									

Taxon	BDHW-01	BEVE-01	BRCH-04	BSNL-01	FOXH-01	LBEA-01	PECK-01	STOC-00	STOC-01	WODC-01	USOP-00	USOP-02	USOP-03	USOP-03A	USOP-03B	USOP-04	USOP-04A	USOP-04B	USOP-05	USOP-06
Rhyacophila mainensis		1	3						2			2	2					1	3	7
Rhyacophila manistee			1			1			2				3	6	3			2		
Rhyacophila sp.					2						1	1								
Serratella deficiens			2																	
Serratella serrata														4	11	15	13	9	20	9
Serratella sp.												1								
Simulium sp.	2	3	8	3	2			1	1		5	55	7	2	2	12	2			2
Stenacron interpunctatum											1									
Stenelmis sp.	1	1				1		2	2				1	2			1			7
Stenonema sp.	1	9	2		1	13	1	9	13	31		14	26	8	2	4	15	7	27	1
Stenonema vicarium		6		1		41	4			7	4						2	18	35	24
Sublettea sp.								2												
Sweltsa sp.				3	4		4			1	1									
Tallaperla sp.							2													
Tanytarsus sp.																	1			
Thienemanniella xena													1							
Thienemannimyia gr. spp.			1					1		2	3	2	1				1			
Tribelos sp.																1				
Turbellaria			1																	
Tvetenia sp.				1							4	1								
Tvetenia vitracies			2					4	2	3		8	12	14		20	6	10	2	3
Undet. Leptophlebiidae									1					1			1			
Undet. Lumbricina						1									1		1	2	2	3
Undet. Lumbriculidae			34		1		3						2		2	2	3	38		29
Undet. Turbellaria	1				1									5	5		2	2	3	1

Table 6. Macroinvertebrate taxa collected from the Upper Esopus Creek watershed during the 2010 sampling season.

Taxon	BDHW-01	BEVE-01	BRCH-04	BSNL-01	FOXH-01	LBEA-01	PECK-01	STOC-00	STOC-01	USOP-00	USOP-02	USOP-03	USOP-03A	USOP-03B	USOP-04	USOP-04A	USOP-04B	USOP-05	USOP-06	WODC-01
Ablabesmyia mallochi	1										1									1
Acentrella turbida	20	3	23	30	35	2	26	10	1		2	7	9	19	83	11	14	20	2	23
Acroneuria abnormis	1	3	1		8	2			2			1	1	1						1
Acroneuria sp.	1					11	1								1			1	1	
Agnetina capitata	8	6	12		1		6	15	7	2	3	1	3		2	1	1	2	2	2
Antocha sp.		4	4	1	1	2	1	1	3	2	2			1	1		2	2		4
Apatania sp.	1						1						1							
Atherix sp.			1				2	2		4		1	1			1			1	1
Atrichopogon sp.						1	1													
Baetis flavistriga	22	1	18	7	13	5	29	17	7	1	7	10	9			2		1	3	4
Baetis intercalaris	2	9	2		3	18		7	4			5	8			1	2	8	6	
Baetis sp.															1					
Baetis tricaudatus	1		3	16	4		9			2		2	2				1			6
Baetisca sp.										2										
Bezzia sp.									1		1		1							1
Undet. Blephariceridae				1																
Brachycentrus americanus				11	1		3			22					2					
Brachycentrus appalachia			3								2		1							
Brillia sp.																		1		
Caecidotea sp.														3	1					
Caenis sp.						1	1													
Cambarus sp.	4		3		1	1			1					1					2	1
Cardiocladius obscurus												1		8	1		6	3		12
Cheumatopsyche sp.	21	5	5	17	45	21	54	18	11	22	6	7	1			4	6	5	11	13
Chimarra aterrima?						11						1							2	

Taxon	BDHW-01	BEVE-01	BRCH-04	BSNL-01	FOXH-01	LBEA-01	PECK-01	STOC-00	STOC-01	USOP-00	USOP-02	USOP-03	USOP-03A	USOP-03B	USOP-04	USOP-04A	USOP-04B	USOP-05	USOP-06	WODC-01
Cladotanytarsus sp.																	1			
Crangonyx sp.																20				
Cricotopus bicinctus	4								41	22	3		8					5		
Cricotopus sp.		4	4	1			3		2	15		1		47	8		4		2	
Cricotopus trifascia gr.																1	2	2		
Diamesa sp.	1		7				1	3				1		2						
Dicranota sp.	3	1	13	4	10	1	17	4	5	7	1						1		1	3
Dicrotendipes sp.										5										
Diphetor hageni	1		1		2		3													
Dolophilodes sp.	12	78	39	64	11	34	18		8	13	3	23	17	1		2	23	7	30	1
Drunella cornutella			5		4		1			3										
Undet. Empididae	1			1	1		1	1												
Undet. Enchytraeidae	1						1													
Epeorus sp.	13	23	10	3	3	17	1	17	6	1	10	36	42	1	3	5	16	42	34	3
Ephemera sp.						1														
Ephemerella aurivillii				19						15										
Ephemerella sp.	6		9	5	1	1	10	2	1	4	10	8	11	32	8	3	3	1		8
Ephydridae					2															
Eukiefferiella devonica gr.				1		2								1				1		
Eukiefferiella pseudomontana gr.			2																	
Eurylophella funeralis			1			3	2			3										
Glossosoma sp.	2				2	3	4	7			1									2
Hemerodromia sp.						1			1					1						
Heptagenia sp.	2		11	17	22		2			2	1	1	3		16	8	14	5		5
Hexatoma sp.	11	7	7	7	10		2	12	4	1	7	7	1							13
Hydropsyche bronta								10	1			1	5	1	1	8		5	2	
Hydropsyche morosa	1	27	2	1		3		24	26	1	5	6	13	9	26	50	51	55	42	2
Hydropsyche slossonae	45	46	27	23	45	21	21	19	17	32	26	15	19	21	25	6	2	1	1	46

Taxon	BDHW-01	BEVE-01	BRCH-04	BSNL-01	FOXH-01	LBEA-01	PECK-01	STOC-00	STOC-01	USOP-00	USOP-02	USOP-03	USOP-03A	USOP-03B	USOP-04	USOP-04A	USOP-04B	USOP-05	USOP-06	WODC-01
Hydropsyche sparna	5	23	5	11	7	26	1	6	2	2	5	5	6	18	23	3	6	13	8	1
Hydropsyche ventura				2			2													
Hydroptila sp.		2								1							1			
Isogenoides sp.	11	1	3		3	3	5	18	1	3	4	7	16			1				1
Isonychia sp.	6	28	20	22	13	21	2	78	31	1	79	80	64		2	8	21	30	38	6
Lepidostoma sp.							2			9	3		1			2		1	5	
Leucotrichia sp.		1																		
Leucrocuta sp.	2		2		5	17	7	11	1		9	16	10				7	3	7	1
Leuctra sp.	4	1	16	15	11		14		9	6	8	7	1	2	6	3	5		1	2
Limnephilidae										1										
Limnophila sp.							1													
Limonia sp.					1															1
Undet. Lumbriculidae	1		2		5	2	1				3			22	2	1	5	14	24	
Malirekus iroquois				3	3		1									1				
Micropsectra dives gr.	7	1	9	63	11	2	14		2	33	21	24	8	1						7
Microtendipes pedellus gr.	3	1		1		3	7	19	1	1	1	1	4	12	6	17	4	4	2	6
Microtendipes rydalensis gr.			2			3	2	2	7	1	1	7	1		7	63	16	6	6	4
Mystacides sepulchralis														1						
Nais sp.														60						
Nanocladius sp.		1																		
Neoplasta sp.					1			1												
Nigronia serricornis						8														
Nilothauma sp.									1				1							
Ophidonais serpentina														1						
Optioservus ovalis	8		13		7	1	15	9			4	5	1							2
Optioservus sp.	3			2			3						1	2				3		
Optioservus trivittatus		1	2		1			6	1	15	9	5	1		1			1	5	
Orthocladius (Symposiocladius)				2																

Taxon	BDHW-01	BEVE-01	BRCH-04	BSNL-01	FOXH-01	LBEA-01	PECK-01	STOC-00	STOC-01	USOP-00	USOP-02	USOP-03	USOP-03A	USOP-03B	USOP-04	USOP-04A	USOP-04B	USOP-05	USOP-06	WODC-01
lignicola																				
Orthocladius sp.		1	1		8					21		3					1	3	1	3
Oulimnius latiusculus							2			1										
Pagastia orthogonia			2	6			5			3	3	4	2	2						5
Parachaetocladius sp.											2									
Parachironomus sp.														1						
Paracladopelma sp.									1											
Paragnetina immarginata	39	27	1		1	30	8	14	17			1	2	1	1	3	6	10	11	8
Paragnetina media						6														
Paraleptophlebia sp.	7	3	4		6	2	3	2	7		1	4				2				4
Parametriocnemus sp.		1			1		1													
Pisidium sp.																1				
Plauditus sp.		7	1			7				1	7	1	5		21	22	34	31	18	3
Polycentropus sp.						1	2									1				
Polypedilum aviceps	15		20	21	6	7	43			7	2									9
Polypedilum flavum	22	29	2		1	2		9	100		40	30	50	63	133	96	76	61	74	129
Polypedilum illinoense	1																			
Polypedilum laetum											1		1							
Polypedilum sordens											1									
Polypedilum sp.						1				1										
Potthastia gaedii gr.	3	1	6				2			11										1
Potthastia longimana gr.														17	2	1	1			
Procloeon sp.	11				2	6	1	3	1	1										
Promoresia elegans																				1
Promoresia tardella		3					1			21		1								1
Prostoma graecense		1												17	3	4	5	3		
Protoptila sp.								2												
Psephenus herricki	17	5				48		1	1								1		1	6

Taxon	BDHW-01	BEVE-01	BRCH-04	BSNL-01	FOXH-01	LBEA-01	PECK-01	STOC-00	STOC-01	USOP-00	USOP-02	USOP-03	USOP-03A	USOP-03B	USOP-04	USOP-04A	USOP-04B	USOP-05	USOP-06	WODC-01
Psilotreta sp.			2					1			26	3	2							
Pteronarcys biloba		1	1		2			3		2										
Pteronarcys proteus	4			2	5			1	2											2
Pteronarcys sp.	1	1		2			1						1	1						1
Pycnopsyche sp.										1										
Rheocricotopus robacki	1	1																		
Rheocricotopus tuberculatus										1										
Rheotanytarsus sp.	1	2	7	2	4		2	1		3	1		1				1	1		1
Rhyacophila fuscula			1	2		2				1	1									
Rhyacophila mainensis											3	1					1		1	
Rhyacophila manistee									1		5		1	2						
Rhyacophila minora					1		1													
Rhyacophila sp.			1							2										
Ripistes parasita														16						
Serratella serrata														2	2	2	7	2	3	
Sialis sp.								1												
Simulium sp.				6	1		1			3							4			2
Slavina appendiculata														1						
Stenelmis sp.					1	3		1	6	3		2					6	5	5	
Stenonema ithaca																1		1	5	
Stenonema sp.	3	2	40	2	7	3	3		17	5	55	24			1	7	6	5		1
Stenonema vicarium	12	29	21		17	28	6	34	28	6		21	58		1	34	24	29	36	29
Stylaria lacustris														1						
Sublettea coffmani		1			1		1							1						
Sweltsa sp.	1				3		6	1	1	4	1	1	1						1	1
Synorthocladius sp.										1										
Tallaperla sp.	1	3					2			2										1
Undet. Tanytarsini	2													1						

Taxon	BDHW-01	BEVE-01	BRCH-04	BSNL-01	FOXH-01	LBEA-01	PECK-01	STOC-00	STOC-01	USOP-00	USOP-02	USOP-03	USOP-03A	USOP-03B	USOP-04	USOP-04A	USOP-04B	USOP-05	USOP-06	WODC-01
Tanytarsus sp.	3		1		2		3			7		3			1				2	
Thienemanniella sp.	2		2						1											
Thienemannimyia gr. spp.	3	4		1		3	6	6	7	35	11	6	3	1					1	3
Tipula sp.										1										
Tribelos sp.	14						1		2	1										
Tvetenia sp.	2			5						1										
Tvetenia vitracies				1			1	1	3		1	2	1		8	1	10	6	3	3
Undet. Lumbricina						3								4		1	1	1		
Undet. Turbellaria		1									1	1	1	1	1	2	2			3

Table 7. Summary of basic field physicochemical parameters collected in the Upper Esopus Creek watershed during the 2009 and 2010 field seasons. Field parameters for STOC-00, 2010 were not recorded due to field sampling errors.

SBU-ID	Year	Depth	Width	Current	Embed.	Temp	Conduct	pH	DO	%Sat.	Sal.	Rock	Rubble	Gravel	Sand	Silt
BDHW-01	2009	0.2	7	100	40	19.1	49	7.3	9.7	105	0.02	20	30	40	10	0
BDHW-01	2010	0.2	8	80	40	19.0	76	7.3	9.6	104	0.03	20	40	30	5	5
BEVE-01	2009	0.2	9	100	35	18.2	70	7.6	9.9	105	0.03	25	40	25	10	0
BEVE-01	2010	0.2	4	80	10	20.7	141	7.4	9.2	103	0.07	35	40	15	5	5
BRCH-04	2009	0.2	7	100	40	14.7	110	7.2	10.5	103	0.05	20	40	25	15	0
BRCH-04	2010	0.2	8	50	20	21.0	149	6.9	9.3	105	0.07	15	35	40	10	5
BSNL-01	2009	0.1	6	83	30	13.9	69	7.1	10.6	102	0.03	10	40	40	10	0
BSNL-01	2010	0.2	10	80	30	18.0	88	4.7	10.0	109	0.04	10	30	45	10	5
FOXH-01	2009	0.1	4	91	30	16.8	47	7.0	9.6	99	0.02	15	35	40	10	0
FOXH-01	2010	0.2	4	50	30	19.0	68	5.8	9.4	103	0.03	25	30	30	10	5
LBEA-01	2009	0.3	8	100	40	19.5	69	7.3	9.3	102	0.03	30	40	20	10	0
LBEA-01	2010	0.2	8	70	40	20.0	123	4.1	8.8	97	0.06	30	30	30	10	0
PECK-01	2009	0.1	5	100	40	15.8	34	6.6	10.1	102	0.01	30	20	30	20	0
PECK-01	2010	0.2	8	50	50	19.0	48	-	9.7	104	0.02	20	40	30	5	5
STOC-00	2009	0.3	12	100	40	14.9	59	6.9	10.2	101	0.03	20	20	20	20	20
STOC-00	2010	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
STOC-01	2009	0.4	20	85	40	15.7	60	7.5	10.1	102	0.03	20	20	20	20	20
STOC-01	2010	0.2	10	70	50	19.0	86	7.8	10.0	113	0.04	30	40	20	5	5
WODC-01	2009	0.2	15	100	35	18.0	31	7.1	9.9	105	0.01	35	40	20	5	5
WODC-01	2010	0.2	10	60	35	20.0	53	6.1	9.8	109	0.02	35	40	20	5	5
USOP-00	2009	0.3	10	75	30	15.4	34	7.1	9.9	99	0.01	10	40	20	20	10
USOP-00	2010	0.1	3	50	40	16.0	55	6.9	7.9	82	0.02	15	35	30	10	10
USOP-02	2009	0.3	25	100	30	17.5	53	7.3	10.0	106	0.02	0	30	30	30	10
USOP-02	2010	0.3	20	70	20	21.0	94	6.1	9.5	108	0.04	5	50	30	10	5
USOP-03	2009	0.3	30	110	30	18.7	55	7.4	9.8	105	0.02	10	30	30	20	10
USOP-03	2010	0.2	30	60	20	22.0	97	7.0	9.2	105	0.04	5	30	50	10	5
USOP-03A	2009	0.2	35	90	30	8.6	57	7.1	9.5	101	0.03	10	30	30	20	10
USOP-3A	2010	0.2	20	80	20	18.0	102	7.5	9.7	102	0.05	5	35	45	10	5
USOP-03B	2009	0.2	35	110	10	14.6	63	6.9	10.5	103	0.03	0	20	30	30	20
USOP-03B	2010	0.6	40	100	25	22.0	113	6.9	8.2	93	0.05	5	40	40	10	5
USOP-04	2009	0.3	40	110	30	14.9	62	6.9	10.2	100	0.03	10	30	30	20	10
USOP-04	2010	0.4	35	140	20	21.0	113	6.7	8.2	93	0.05	15	35	35	5	5

SBU-ID	Year	Depth	Width	Current	Embed.	Temp	Conduct	pH	DO	%Sat.	Sal.	Rock	Rubble	Gravel	Sand	Silt
USOP-04A	2009	0.4	55	125	30	15.7	58	7.3	10.2	102	0.03	0	30	40	20	10
USOP-04A	2010	0.3	55	80	10	22.0	110	7.1	8.4	96	0.05	5	40	40	10	5
USOP-04B	2009	0.3	45	125	50	17.1	62	7.5	10.7	110	0.03	20	35	35	10	0
USOP-04B	2010	0.3	40	110	25	23.0	110	7.5	8.6	99	0.05	20	40	20	10	10
USOP-05	2009	0.4	35	110	40	17.9	60	8.1	10.2	107	0.03	10	20	40	20	10
USOP-05	2010	0.4	35	140	20	24.0	110	7.9	8.8	104	0.05	10	40	40	5	5
USOP-06	2009	0.4	64	110	50	18.9	85	7.0	10.1	108	0.04	30	35	25	10	0
USOP-06	2010	0.3	75	60	25	25.0	113	7.8	8.2	98	0.05	10	35	35	10	5

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